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PHOSPHORUS LOADING
IN THE QU'APPELLE RIVER, 1971 TO 1983

FINAL REPORT

SEPTEMBER, 1986

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ENVIRONMENT CANADA

WATER QUALITY BRANCH

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ABSTRACT

The 1975 Qu'Appelle Agreement between the Saskatchewan and Canadian governments provided funds to improve sewage treatment and agricultural practices to reduce nutrient input to the Qu'Appelle River and thereby improve the quality of the Fishing Lakes. During the ten year agreement 5.6 million dollars were spent, much of this for a tertiary treatment plant for the City of Regina sewage. To assess the effect of this expenditure on the nutrient load into the Fishing Lakes, the historical nutrient data (1971 to 1983) for the Qu'Appelle River was examined. This examination shows that the initiation of phosphorus removal from the Regina sewage effluent has substantially reduced the phosphorus load in the Qu'Appelle River basin. It is estimated that the reduction may be as much as 80 percent in Wascana Creek and 30 percent in the Qu'Appelle River as it enters Pasqua Lake.

RESUME

L'Entente sur la vallée de la Qu'Appelle, conclue en 1975 entre la Saskatchewan et le gouvernement fédéral, prévoyait l'affection de crédits pour l'amélioration des méthodes de culture et des procédés de traitement des eaux usées afin de réduire l'apport de substances nutritives dans la Qu'Appelle, ce qui permettrait d'améliorer la qualité de l'eau des lacs Fishing. Pendant les dix années de cette Entente, la plus grande partie des 5,6 millions de dollars qui ont été dépensés est allée à la construction d'une usine d'épuration tertiaire pour les eaux usées de Regina. On a étudié les données sur la charge de substances nutritives dans la Qu'Appelle (1971 a 1983) afin de voir dans quelle mesure la construction de cette usine avait contribué à l'amélioration de l'eau des lacs Fishing. Cet examen a motré que depuis qu'on a commercé à enlever le phosphore dans les eaux d'égout de Regina, la quantité de phospore dans le bassin de la Qu'Appelle a été réduite sensiblement: on estime que la réduction peut atteindre 80 p. 100 dans le ruisseau Wascana et 30 p. 100 dans la Qu'Appelle, là où elle se jette dans le lac Pasqua.

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1.0 SUMMARY AND CONCLUSIONS

Examination of historical data (1971 to 1983) shows that the initiation of phosphorus removal from the Regina sewage effluent has substantially reduced the phosphorus load in the Qu'Appelle River system downstream to Pasqua Lake. The greatest reduction occurred in Wascana Creek, where reduction in the annual phosphorus load in the order of 80 percent has occurred. In the Qu'Appelle River the reduction in annual phosphorus load decreases with distance from Wascana Creek with the reduction above Pasqua Lake being about 30 percent. Despite the 85 percent removal of phosphorus from the Regina sewage effluent, there is still a significant amount of phosphorus (mean 24 tonnes annually) entering the Qu'Appelle River system as a result of the Regina sewage effluent. The phosphorus load from the sewage effluent is estimated to represent 80 percent of the phosphorus load in Wascana Creek at the confluence with the Qu'Appelle River and 26 percent of the phosphorus load in the Qu'Appelle River at Lumsden from 1977 to 1983. This is assuming no instream loss a reasonable assumption considering the long term phosphorus loads.

In 1982 the City of Moose Jaw began spray irrigating with its sewage effluent during the summer months. Work is continuing which will allow storage of sewage effluent from the non-irrigation season and increase the land area for irrigation. Due to the short period of time that spray irrigation has been in effect and the sparse nature of the data, it is not possible to effectively assess what impact spray irrigation is having on the nutrient quality of the Qu'Appelle River at this time.

2.0 INTRODUCTION

The Fishing Lakes on the Qu'Appelle River are a major recreational resource for the people of southern Saskatchewan. The Qu'Appelle Basin Study (1972) conducted in the early 1970's identified excessive algal and plant growths as the major water related problems which interfered with the recreational use of these lakes. This highly eutrophic condition was considered to be the result of large nutrient loads to the basin.

Induced, or 'cultural', eutrophication, is generally caused by excessive input of plant nutrients (eg. phosphorus) and sediment from sewage disposal, livestock operations, fertilizer runoff from agricultural land, breaking of natural land for cultivation causing increased erosion, and other activities. This increased input of nutrients can greatly

stimulate algal and other aquatic plant growth, resulting in undesirable changes in the chemical, physical, and biological characteristics of the water body. Cultural eutrophication is reversible to a large extent, although such efforts may require extensive control programs.

The natural eutrophication of the Qu'Appelle Fishing Lakes was well advanced before European settlement of the prairies. Evidence of this is found in reports from early explorers who found extensive algal blooms on the lakes during the summer and from the high levels of phosphorus found in sediment cores from depths representing presettlement deposition (Allan et al., 1980.). Man's activities, however, have greatly increased the rate of eutrophication in the lakes. Initially the breaking of the land for farming increased the sedimentation rates and the input of nutrients due to the increased erosion of the exposed nutrient rich soil. As the population grew and cities developed sewage disposal further increased the nutrient load to the Qu'Appelle River Basin. The Qu'Appelle Basin Study (1972) reported that nearly 70 percent of the phosphorus and nitrogen in the Qu'Appelle River system originated from municipal sewage systems.

To reduce the eutrophication rate, the Qu'Appelle Basin Study Board (1972) recommended that the cities of Regina and Moose Jaw reduce their phosphorus input to the Qu'Appelle River Basin and that major livestock operations modify their practices. Recommendations were also made for further water quality monitoring and research to clarify the problems and to determine solutions.

In 1975, the Qu'Appelle Agreement was signed by the Canadian and Saskatchewan Governments. The objectives of the agreements were as follows:

(a) to ensure the long term productivity of the Qu'Appelle Valley's recreation and tourism resource base, including the natural environment, historic resources, cultural heritage, and hospitality industry;

(b) to increase the benefits from utilization of this resource base in terms of:

    (i) improved incomes and greater diversity of employment opportunities for residents of the Qu'Appelle Valley, and

    (ii) increased recreational opportunities for residents of the nearby urban centres, particularly Regina and Moose Jaw, thereby influencing individual locational decisions of employers and members of the labour

force in favour of these centres; and

(c) to improve the management of the land and water resources of the Qu'Appelle Valley to meet existing and future uses of these resources.

As part of the Qu'Appelle Agreement, approximately 5.6 million dollars has been spent primarily to reduce the phosphorus input to the Qu'Appelle River system (Reid Crowther/DPA Consortium, 1984) and thereby reduce the eutrophication rate of the lakes or at least prevent it from worsening. Recent advances in the knowledge of factors affecting water quality have led some researchers to question if such controls alone will result in improvements in the highly eutrophic state of the Fishing Lakes (Allan, 1980).

In 1979, it was recognized by the Qu'Appelle Valley Management Board, henceforth referred to as the 'Board', as well as Federal and Provincial agencies, that the ongoing water quality monitoring activities were insufficent to assist the Board in determining the effects of the pollution abatement measures undertaken. As a result, the concerned agencies jointly recommended (Reid, 1979) that:

(1) an evaluation be carried out of existing data for Wascana Creek and Qu'Appelle River below Wascana Creek;

(2) trends in nutrient loadings to and from the Fishing Lakes be determined;

(3) lake productivity surveys be conducted; and

(4) regular ongoing monitoring by government agencies be continued.

Environment Canada, Water Quality Branch (Branch) agreed to address the second activity, proposing a long term five-year study with the following specific objectives:

(1) conduct intensive sampling of the Qu'Appelle River to accurately determine nutrient loading into and out of the Fishing Lakes.

(2) estimate the effect of the City of Regina's tertiary treatment plant on the phosphorus loading to the Fishing Lakes. Effluent from the City of Moose Jaw will also be reviewed in this same context.

(3) estimate trends in the nutrient quality, loading and productivity of the Qu'Appelle River above Pasqua Lake and below the Fishing Lakes.

To meet these objectives the Branch began its proposed five year intensive monitoring program in the spring of 1980 (funded by both Canada and Saskatchewan). The study terminated prematurely in June 1983 when the required resources were no longer forthcoming for continued monitoring. As a result intensive sampling results are available for only 39 months (April 1980 to July 1983) at two sites on the Qu'Appelle River. In addition to the intensive sampling program, phosphorus data for locations upstream of the Fishing Lakes were gathered from other agencies in order to examine the effect pollution abatement measures have had on the nutrient load to the Qu'Appelle Fishing Lakes.

This report addresses the last two objectives by examining the effects of pollution abatement measures on the phosphorus levels in the Qu'Appelle River upstream of the Fishing Lakes using all the available data. A detailed examination of the intensive nutrient monitoring program conducted by the Water Quality Branch is presented under separate cover (Munro, 1986). An assessment of periphyton productivity in the Qu'Appelle River above and below the Fishing Lakes was presented by Munro (1985).

2.1 STUDY AREA

The Qu'Appelle River Basin extends approximately 400 km, from its headwaters near Lake Diefenbaker to its confluence with the Assiniboine River, and drains an area of approximately 52,000 square kilometres (Qu'Appelle Basin Study Board, 1972). Th Qu'Appelle River is a mature river having a broad flood plain and well developed meanders. The river flows through seven lakes (Figure 1), these being Buffalo Pound Lake, the Fishing Lakes (Pasqua, Echo, Mission and Katepwa), Crooked Lake and Round Lake. Last Mountain Lake discharges into the Qu'Appelle River through Last Mountain Creek. During periods of high flow, however, water from the Qu'Appelle River may flow unregulated into Last Mountain Lake. During periods of low flow, a control structure near Craven can be used to divert Qu'Appelle River water into Last Mountain Lake. Water may also enter the Qu'Appelle River system from the South Saskatchewan River by a diversion channel from Lake Diefenbaker.

There are numerous minor tributaries to the Qu'Appelle River and about ten major tributaries, of which the Moose Jaw River and Wascana Creek are the most significant. The tributaries generally have their highest flows during spring runoff, with little or no flow during the remainder of the year. During these low or no flow periods, river reaches

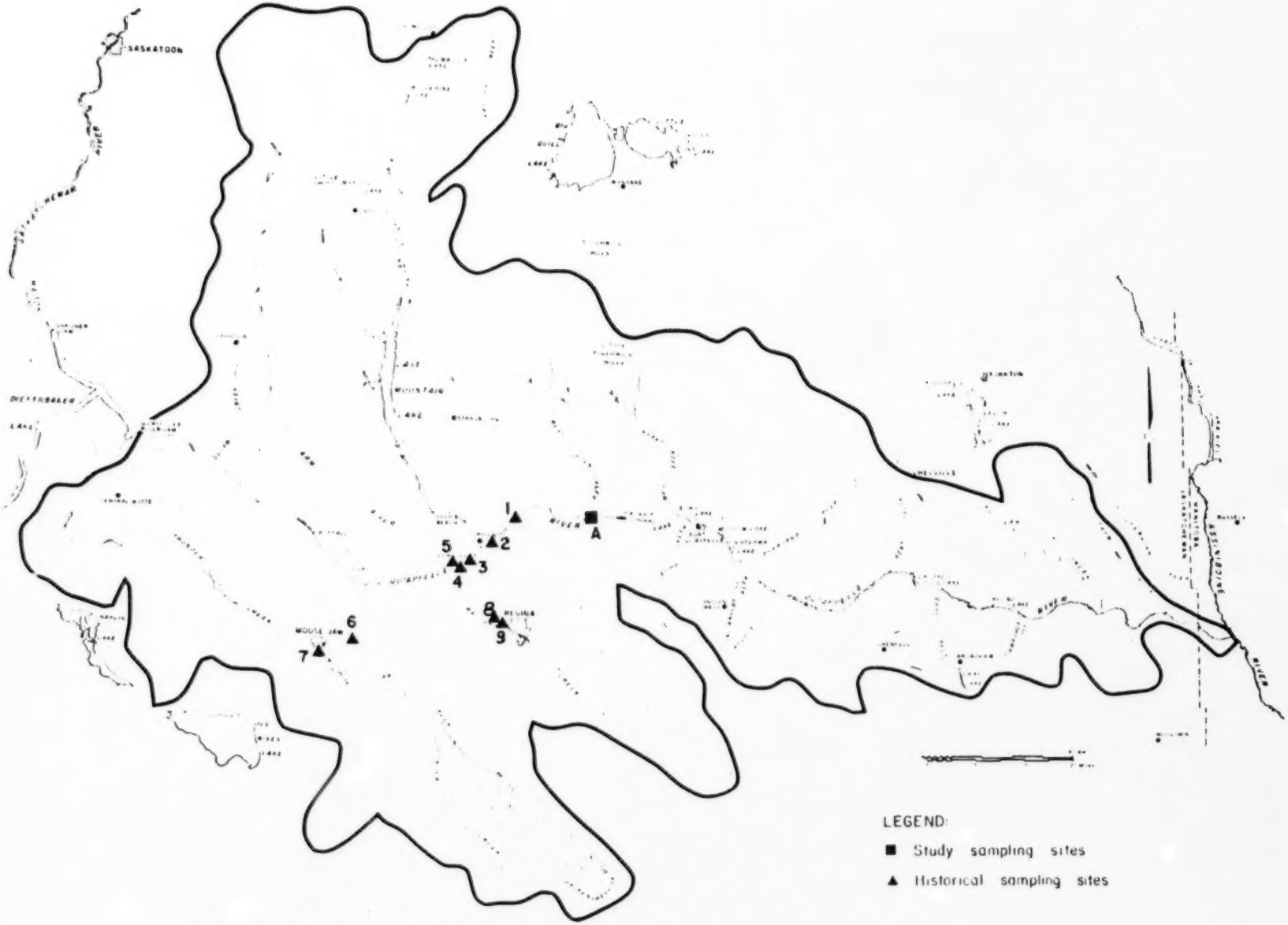

Figure 1 Qu'Appelle River Basin Showing Data Collection Locations.

often become plugged with aquatic weed growth.

The Qu'Appelle River Basin provides water for municipal and industrial use, agriculture (irrigation and livestock watering), recreation and wildlife habitat. The major portion of the basin is agricultural land, used essentially for cereal cropping. However, a substantial number of livestock operations exist throughout the basin, mainly along the river valley and the tributaries. The large population centres, Regina and Moose Jaw, are the major users of the Qu'Appelle River water; both cities draw their municipal water supply from Buffalo Pound Lake and discharge their sewage effluents to Wascana Creek and the Moose Jaw River, respectively.

The soils in 75 percent of the upper Qu'Appelle River Basin are dark brown Chernozemic soils, with a soil capability classification from Class 2 to Class 5. These soils are developed on lacustrine, alluvial lacustrine, alluvial glaciofluvial and glacial till parent materials. The main drainage channels and their flood plains occupy about ten per cent of the upper basin and are azonal soils characteristic of the alluvium and tillwash complexes (ARDA, 1968).

The climatic condition in the Qu'Appelle River Basin is characterized by hot summers, cold winters and moderate precipitation. Mean annual precipitation ranges from 350 to 420 millimetres within the basin, of which 25 per cent occurs as snow (Qu'Appelle Basin Study Board, 1972). Variation in precipitation alters the effective drainage area of the Qu'Appelle River dramatically due to the relatively flat land. The effective drainage area in a dry year may only be 50 percent that of a wet year (Tones, 1981).

The study area was limited to the Moose Jaw River, Wascana Creek, and the upper portion of the Qu'Appelle River from its confluence with the Moose Jaw River to the outlet of the Fishing Lakes.

3.0 METHODS

In April, 1980, the Water Quality Branch began its intensive sampling program to determine nutrient loads into and out of the Fishing Lakes. To accomplish this, two sampling sites were established above and below the Fishing Lakes. These were collocated with Water Survey of Canada hydrometric stations. For the purpose of this report only data from the upstream site are used.

Samples for nutrient analysis were collected every three days from April, 1980 to April, 1983 after which the frequency was reduced to every three and a half days until the end of June 1983. At the upstream site the samples were collected using an automatic composite sampler which collected 100 millilitres of water every two hours and composited that over the collection period. This sampling program produced almost 400 samples over the 39 months of sampling. Cross-sectional and quality control sampling at each site represented approximately the same number of samples at each site. A complete description of the method used in the intensive sampling program is given by Munro (1986).

As the intensive sampling program began about three years after the completion of the Regina Tertiary Treatment Plant, it was necessary to gather as much of the available historical data as possible in order to examine the influence of pollution abatement activities on the nutrient quality of the Qu'Appelle River above the Fishing Lakes. Data were obtained from various sources including the City of Regina, Saskatchewan Department of the Environment, Qu'Appelle Implementation Board, and Environment Canada (Table 1).

Total phosphorous data were assembled for the period January, 1971 to July, 1983. From these data, monthly total phosphorus levels were determined for months having more than one value. For months with only one value, that value was assumed to represent the monthly mean. A best estimate of the phosphorus level was made for months when no data were available by taking the mean of the samples collected during the months before and after the missing month. An exception to this procedure was made when missing data occurred in a month in which a major change in the hydrograph occurred. In these cases, the estimates of concentrations were made from one or more of the following data sets: concentrations observed in years during periods of similiar flows; and concentrations observed at upstream and downstream locations during the same month. The computed monthly phosphorus concentrations were assumed to represent the mean concentration for the month and were used in the calculation of historical monthly phosphorus loads. If more than three consecutive months had no data, no estimates were made for these missing months.

Historical phosphorus loads were calculated by multiplying the monthly discharge, obtained from Water Survey of Canada (1980; 1981; 1982; 1983) by the estimated mean monthly phosphorus concentration. Given the irregular nature of sampling frequencies by the various agencies, the difference in analytical methods through the years and

Table 1. Data Collection Locations and Sources Of Data.

Map Location	Location	Period of Record	Data * Source
A	Qu'Appelle River above Pasqua Lake	1970-1973	WQB
		1980-1983	WQB
		1971-1983	SDOE
		1978-1983	City
1	Qu'Appelle River at Highway # 6	1970-1979	WQB
		1970-1983	SDOE
		1977-1983	City
2	Qu'Appelle River below Craven Dam	1970-1974	WQB
3	Qu'Appelle River at Lumsden	1970-1974	WQB
		1970-1983	SDOE
		1977-1983	City
4	Wascana Creek above Qu'Appelle River	1970-1978	WQB
		1970-1983	SDOE
		1977-1983	City
5	Qu'Appelle River above Wascana Creek	1970-1974	WQB
		1971-1983	SDOE
		1977-1983	City
6	Moose Jaw River at Highway # 301	1970-1978	WQB
		1970-1983	SDOE
7	Moose Jaw River above Moose Jaw	1970-1973	WQB
8	City of Regina Sewage Effluent	1972-1983	SDOE
		1977-1983	City
9	Wascana Creek at Riske's Crossing	1971-1983	SDOE
		1977-1983	City

* - WQB refers to the Water Quality Branch
- SDOE refers to the Saskatchewan Department of Environment
- City refers to the City of Regina

between agencies, the phosphorus load calculations made with these historical data can only be described as a very rough estimate of the actual loads and provides only a general indication of the phosphorus quality in the basin.

4.0 RESULTS AND DISCUSSION

Since the Qu'Appelle Basin Study Board report was completed in 1972, considerable effort and money have been spent in an attempt to reduce the nutrient loading to the Basin. More than 1000 livestock operations were assessed and 184 of the 322 which were considered to need improvement have been relocated and/or have had practices improved (Reid Crowther/DPA Conortium, 1984). Moose Jaw initiated spray irrigation of approximately 500 hectares with its sewage effluent in June, 1982. Regina began upgrading of its secondary sewage treatment system with the offical opening of a tertiary treatment plant in July, 1975. When the plant became fully operational in June of 1976, algae and 80 to 85 percent of the total phosphorus were removed. Prior to this improvement in sewage effluent treatment, the cities of Regina and Moose Jaw contributed 220 tonnes of phosphorus annually to the Qu'Appelle River Basin (Qu'Appelle Basin Study Board, 1972).

The effects of improvements in livestock practices on the water quality in the Qu'Appellle system have not been subject to site specific investigations; hence, they are at this time unquantifiable.

4.1 Regina Tertiary Treatment

4.1.1 Phosphorus Concentration

The Regina sewage treatment plant discharges approximately 0.8 m^3/s of sewage which represents the major component of the Wascana Creek flow except during periods of high flow. The historical phosphorus data (1971 to 1983) for Wascana Creek reflects this major contribution of the Regina sewage effluent, particularly prior to tertiary treatment. Upstream of the sewage discharge (Riske's Crossing), the monthly phosphorus concentration was less than 1 mg/L except on two occasions. Seventy kilometres downstream from the sewage discharge (just above the Qu'Appelle River), the monthly phosphorus concentrations prior to 1976 were almost always in excess of 1 mg/L and frequently in excess of 5 mg/L. After the tertiary treatment plant became operational in 1976, phosphorus

concentrations at this site rarely exceeded 1 mg/L.

Phosphorus concentrations in the Qu'Appelle River upstream of Wascana Creek varied considerably, ranging for the most part between 0.1 and 1.5 mg/L. The higher concentrations generally occurred during the winter period and rapidly decreased with increasing flows during spring runoff. After the spring runoff subsided, the phosphorus concentrations generally increased and were in the range of 0.25 to 0.50 mg/L through the open water period. A similar seasonal pattern in monthly total phosphorus concentrations occurred at the sampling sites on the Qu'Appelle River downstream of Wascana Creek. The phosphorus concentrations tended to be greater at the site closer to Wascana Creek, reflecting the impact of discharge from Wascana Creek. The spring decrease in phosphorus is no doubt a reflection of dilution by spring melt water and the winter peak concentrations result from a number of factors including decreased dilution by surface runoff and release of phosphorus by senescent and decaying plants.

At the Lumsden site (site 3), the monthly phosphorus concentration ranged from 0.1 to 5.8 mg/L. For the most part the very high concentrations occurred prior to the spring of 1976, although high phosphorus concentrations (as high as 4.5 mg/L) were found on occasion during winter months until 1980. The generally lower phosphorus concentration since 1976 as in Wascana Creek was a reflection of the phosphorus removal from the Regina sewage effluent.

At the site below Craven Dam (site 5), the total phosphorus level generally appeared to be lower after the spring of 1974 than in previous years. Prior to the spring of 1974, the total phosphorus concentrations at this site were consistantly greater than 0.5 mg/L and ranged as high as 2.5 mg/L; during subsequent years total phosphorus concentrations were generally less than 0.5 mg/L, with the exception of winter samples which occasionally were as high as 3.0 mg/L. The decline in concentration in the spring of 1974 was a function of the very high spring runoff and was seen at all the sampling sites. At the upstream sites, however, the phosphorus concentrations increased again after the spring of 1974.

Above Pasqua Lake (site A), data were very limited prior to 1973. Since that date, there has been no discernible decrease in phosphorus concentration which might coincide with the start of the Regina tertiary treatment plant. This inability to identify a decrease in phosphorus concentration after tertiary treatment began may be primarily a reflection of the limited phosphorus data base.

4.1.2 Phosphorus Loading

A summary of the annual phosphorus loads in Wascana Creek and the Qu'Appelle River based on the monthly historical data from 1971 to 1983 is given in Table 2. These data show a significant decrease in phosphorus load at the sites downstream of the Regina sewage discharge after 1976, which coincides with the start up of the Regina Tertiary treatment plant. This decrease was most apparent in Wascana Creek, where the annual phosphorus load prior to 1977 ranged from 93.3 to 179.6 tonnes and since, then the maximum annual load has been 50.4 tonnes. The monthly phosphorus loads from 1971 to 1983 in Wascana Creek and the Qu'Appelle River (shown in Figures 2 to 6) also show a decrease coinciding with the start up of the tertiary treatment plant. The exception to this was the unusually high load during the 1982 spring freshet at the Lumsden site. The April load recorded there (97.41 tonnes) was the highest monthly load found at any of the sites. This period of high load may, however, be a function of the method used to estimate phosphorus concentration for months in which no data are available, as estimations of the phosphorus concentration were necessary for both March and April in 1982 at this site. The assumption that this high load is incorrect is strengthened by comparison with the loads calculated based on the intensive sampling above Pasqua Lake (Munro, 1986). Munro reports the phosphorus load above Pasqua Lake for April 1982 was 17.9 tonnes. A number of factors could contribute to this difference, including instream phosphorus loss and diversion to Last Mountain Lake, but these factors likely cannot account for all of the difference.

The general decrease in the phosphorus load at sites downstream of the Regina sewage effluent since 1976 suggest that improved sewage treatment has reduced the phosphorus load in the Qu'Appelle River. However, the flow in the Qu'Appelle River Basin since 1976 has been lower than the five years prior to 1976, due to the very high flow from 1974 to 1976 (Table 3). The lower flow since initiation of tertiary treatment could account for much of the decrease in phosphorus loads as the effective drainage of the river would have been reduced. In an attempt to differentiate the effect of flow from the effect of reduced phosphorus input, comparison of the phosphorus loads for years before and after tertiary treatment with similar flow conditions were made. For this purpose four pairings were established (Table 4) and the change in phosphorus load from pre- and post- tertiary treatment were determined. These comparisons show there was significant reduction in phosphorus load at all the sites downstream of the Regina sewage discharge

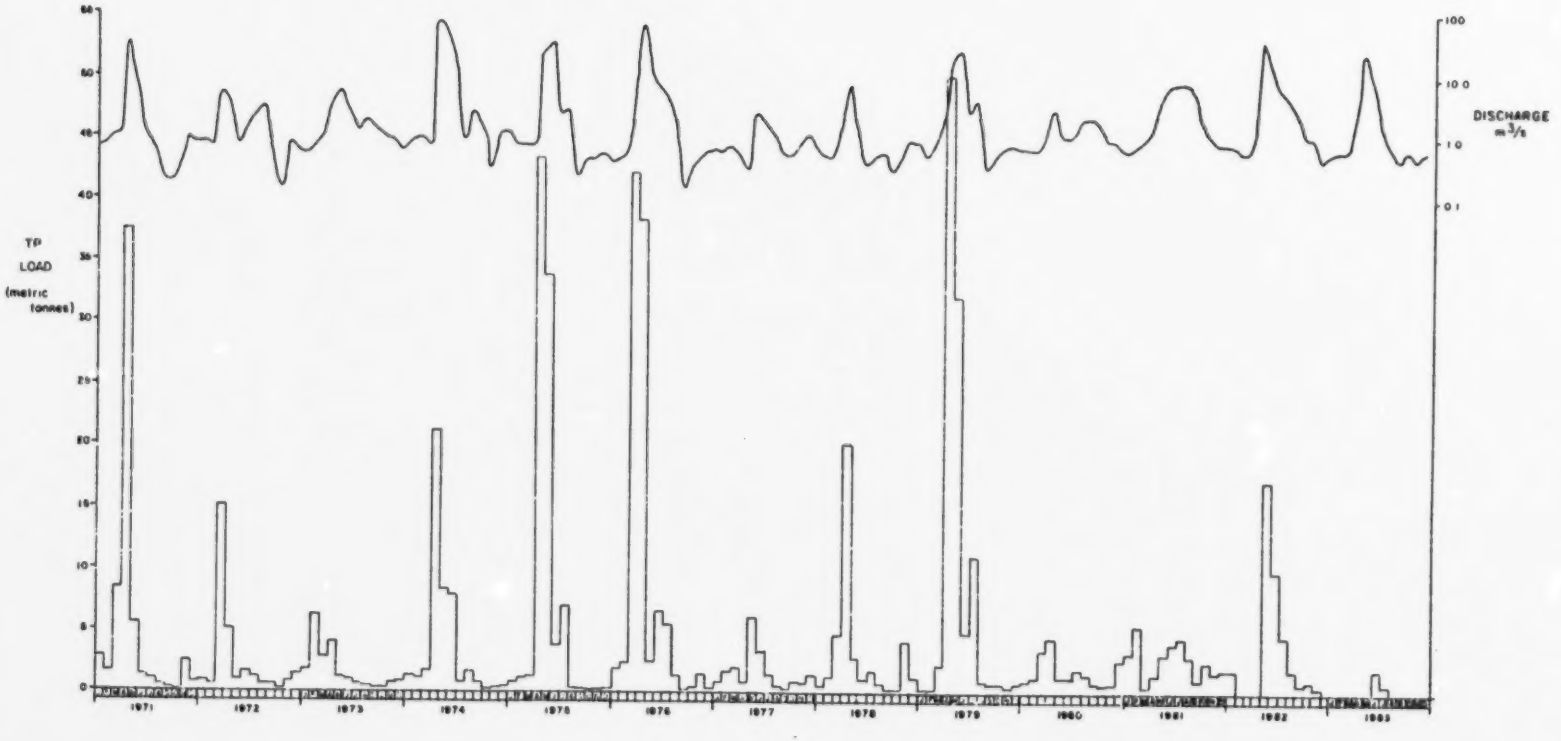

Figure 2 Total Phosphorus Load in the Qu'Appelle River Below Moose Jaw River, 1971 to 1983.

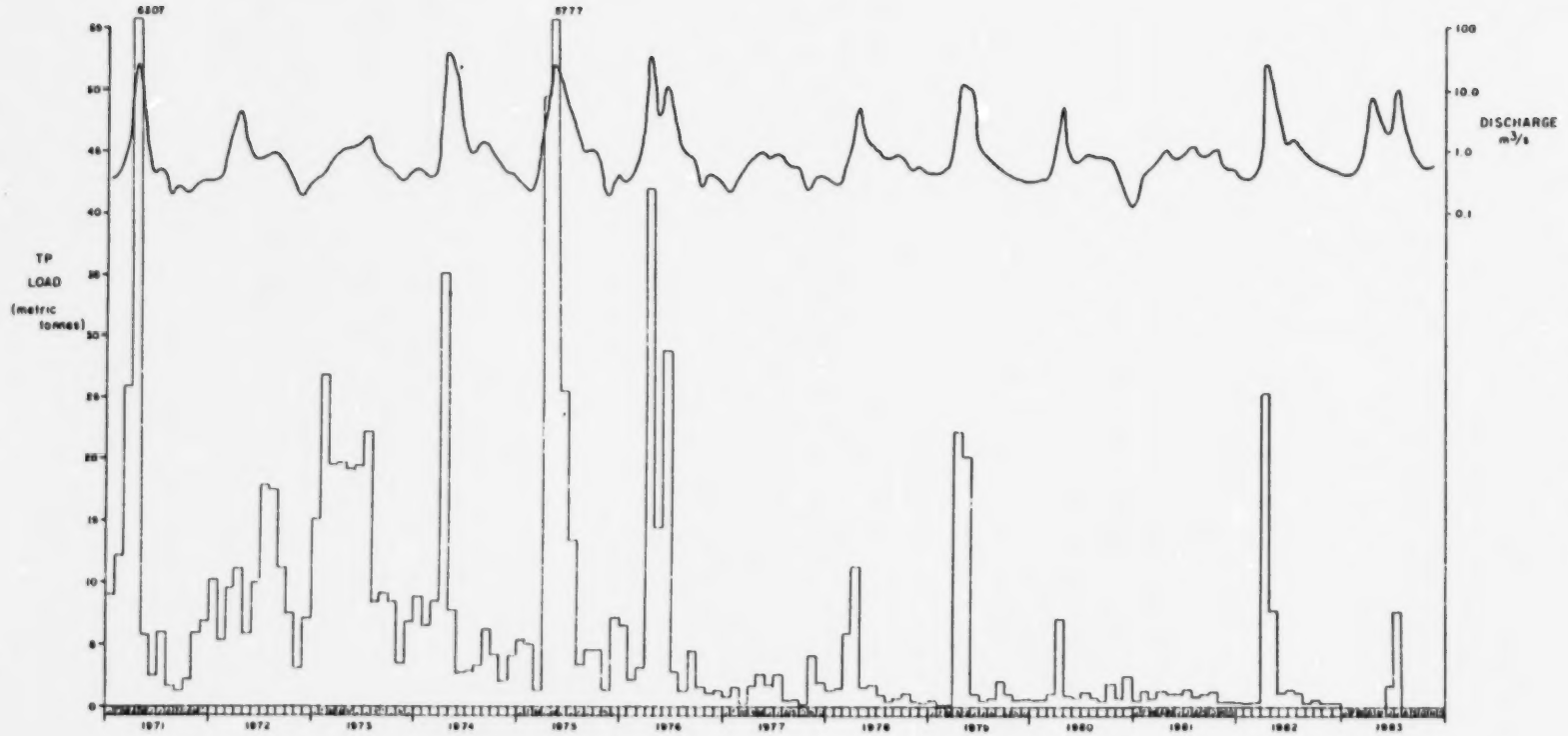

Figure 3 Total Phosphorus Load in Wascana Creek above the Qu'Appelle River, 1971 to 1983.

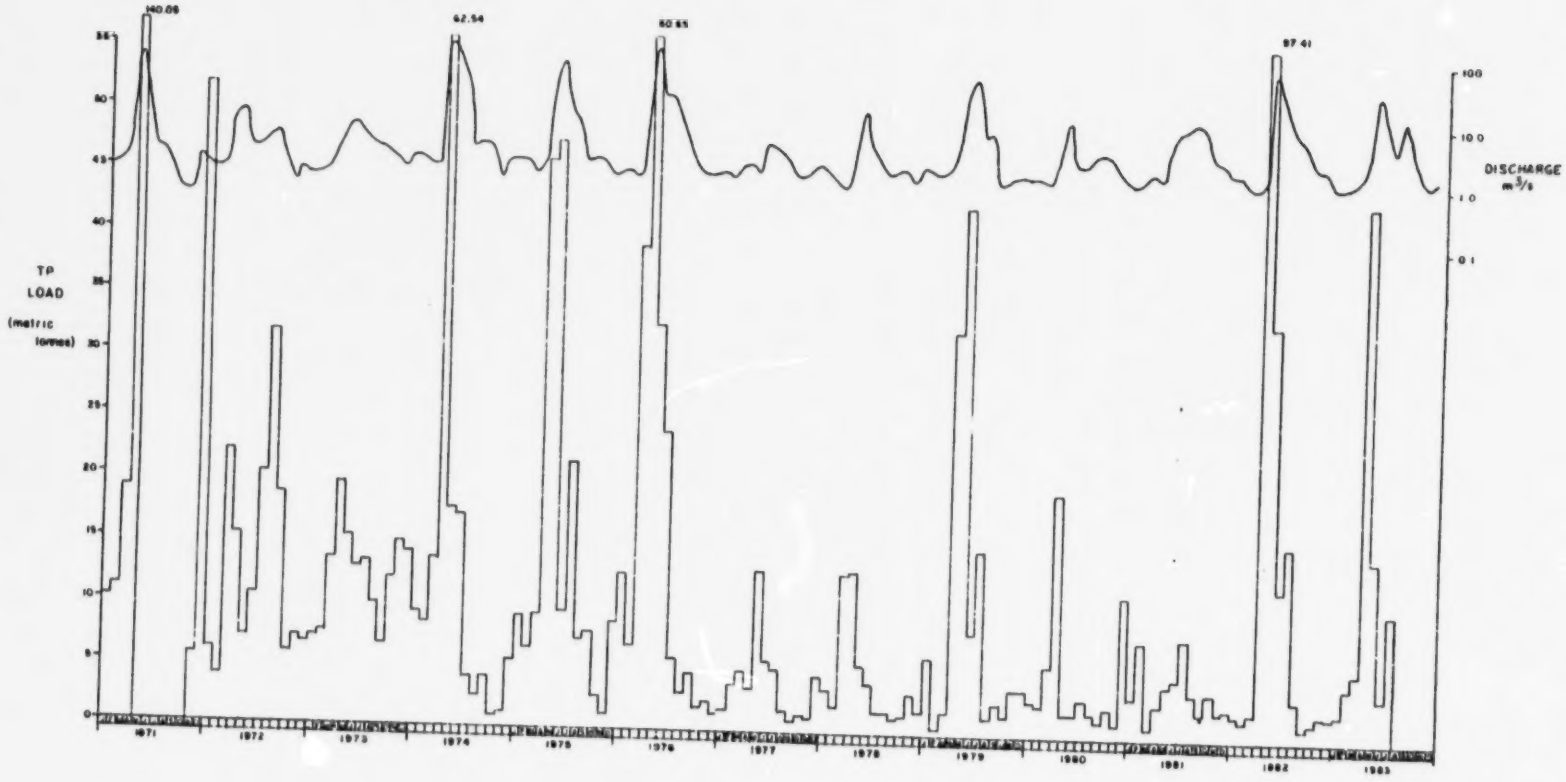

Figure 4 Total Phosphorus Load in the Qu'Appelle River at Lumsden, 1971 to 1983.

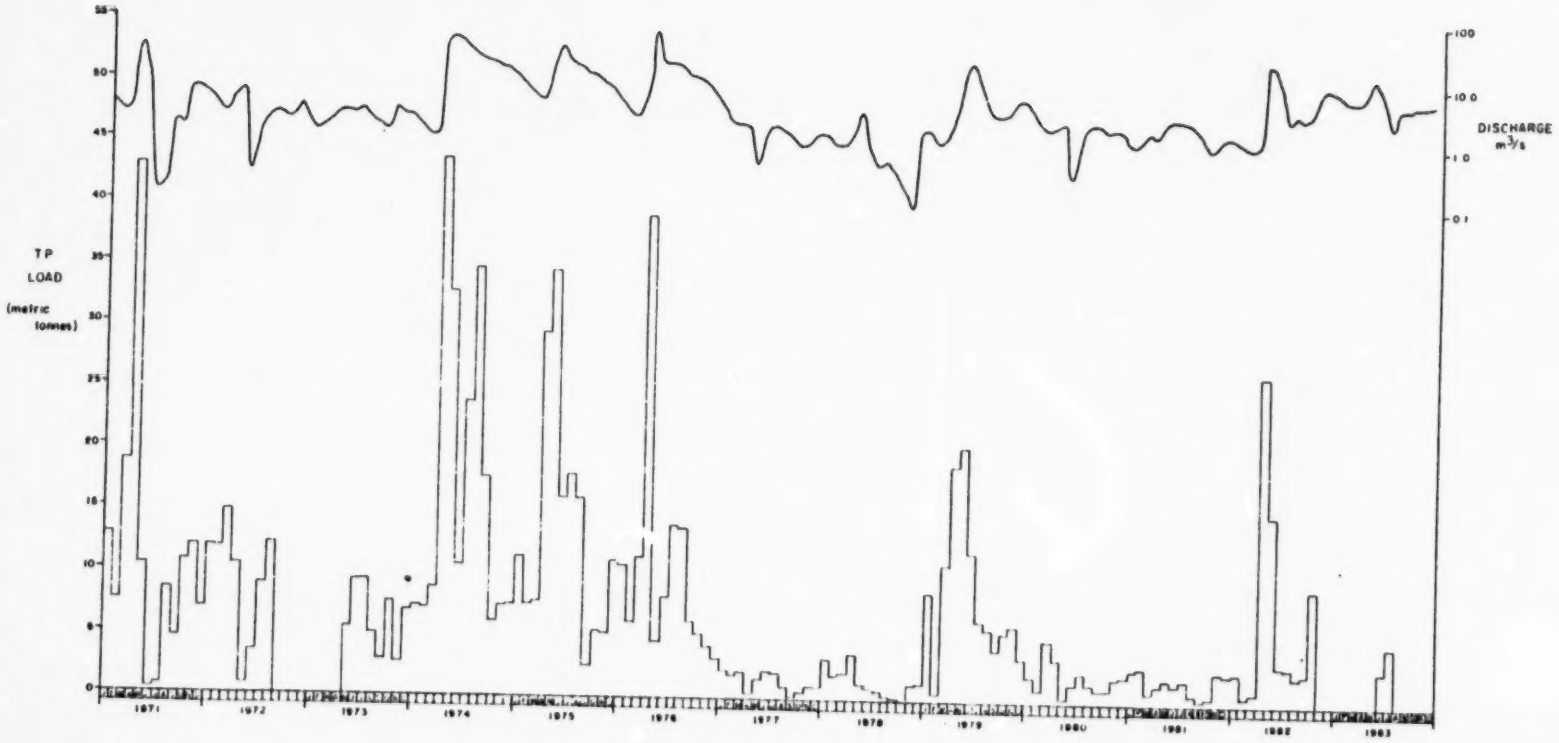

Figure 5 Total Phosphorus Load in the Qu'Appelle River Below Craven Dam, 1971 to 1983.

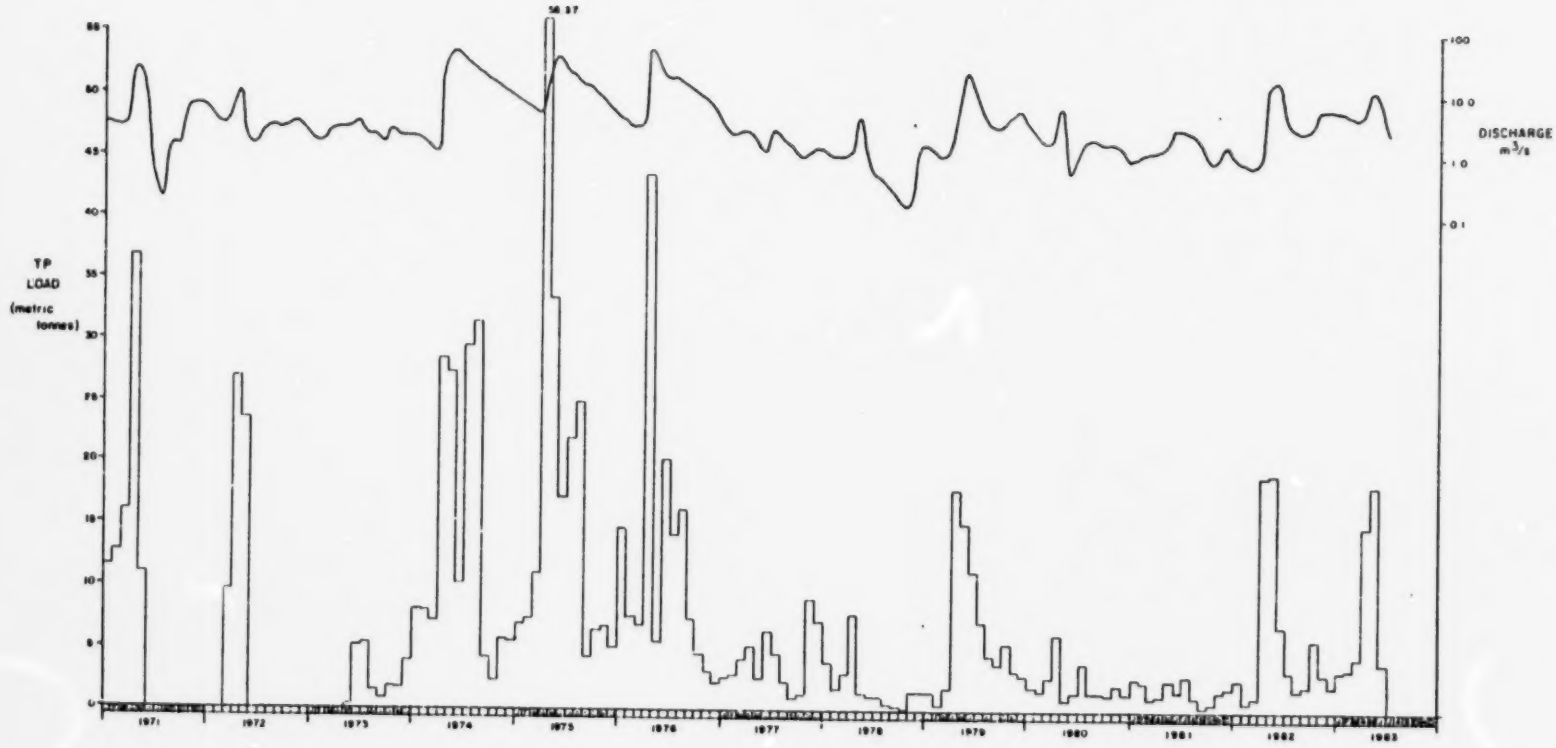

Figure 6 Total Phosphorus in the Qu'Appelle River Above Pasqua Lake, 1971 to 1983.

Table 2. Annual Total Phosphorus Loads (Tonnes) in the Qu'Appelle River and in Wascana Creek, Based on Monthly Samples, 1971 to 1983.

	Qu'Appelle below Moose Jaw River	Wascana Creek above Qu'Appelle	Qu'Appelle at Lumsden	Qu'Appelle below Craven Dam	Qu'Appelle above Pasqua Lake
1971	62.0	143.0	238.0 (6 mos. Jan-Apr & Nov-Dec)*	136.3	88.5 (5 mos. Jan-May)*
1972	28.6	117.0	156.5	74.1 (8 mos. Jan-Aug)*	60.3 (3 mos. Mar-May)*
1973	20.4	153.5	147.8	49.0 (8 mos. May-Dec)*	21.2 (8 mos. May-Dec)*
1974	45.9	93.3	149.5	206.8	169.3
1975	92.1	179.6	177.1	164.8	204.4
1976	103.0	110.3	195.8	126.3	146.2
1977	20.2	20.2	47.9	16.8	49.6
1978	38.8	29.5	52.7	17.4	24.0
1979	104.3	50.4	123.3	103.9	75.6
1980	21.8	18.5	57.2	24.3	27.4 (19.8)**
1981	32.2	10.9	45.7	18.9	20.8 (24.5)**
1982	35.2 (7 mos. May-Nov)*	40.1	184.0	65.4 (10 mos. Jan-Nov)*	68.8 (59.7)**
1983					49.7 (6 mos. Jan-Jun)* (31.2)**

* - time periods in brackets indicate the period for which loads are calculated

** - load calculated with results from the intensive sampling program

Table 3. Summary of Annual Discharge for Wascana Creek and the Qu'Appelle River, 1971 to 1983 (dam^3).

	Qu'Appelle below Moose Jaw River	Wascana Creek above Qu'Appelle	Qu'Appelle at Lumsden	Qu'Appelle below Craven Dam	Qu'Appelle above Pasqua Lake
1971	129,000	94,400	221,000	205,000	204,000
1972	57,900	31,100 (10 mos.)	92,100	97,100	115,000
1973	59,800	25,400	78,100	77,900	75,500
1974	447,000	185,000	690,000	653,000	627,000
1975	185,000	150,000	349,000	414,000	443,000
1976	289,000	171,000	472,000	464,000	464,000
1977	31,500	19,400	53,900	49,300	57,300
1978	39,800	38,000	76,200	34,000	35,500
1979	166,000	84,100	252,000	208,000	204,000
1980	45,300	33,800	81,500	56,400	65,100
1981	105,000	27,100	133,000	57,200	54,700
1982	203,000	125,000	351,000	226,000	203,000
1983 (6 mos.)	112,000	46,800	162,000	120,000	126,000

Table 4. Comparsion of Annual Total Phosphorus Loads in Years with Similar Discharge, Before and After Tertiary Treatment.

STATION		YEARS COMPARED							
		1971 to 1979		1973 to 1978		1973 to 1980		1975 to 1982	
Qu'Appelle below Moose Jaw River	Discharge	129,000	166,000	59,800	39,800	59,000	45,000	185,000	203,000
	Load	62.0	104.0	20.4	38.8	20.4	21.8	92.1	35.2
	Change		+ 67%		+ 90%		+ 7%	(45.9)*	- 23%
	**		+ 33%		+ 180%		+ 88%		- 2%
Wascana above Qu'Appelle	Discharge	94,400	84,100	25,400	38,000	25,400	33,800	150,000	125,000
	Load	143.0	50.4	153.6	29.5	153.6	18.5	179.6	40.1
	Change		- 65%		- 81%		- 88%		- 78%
	**		- 60%		- 87%		- 91%		- 73%
Qu'Appelle at Lumsden	Discharge	221,000	252,000	78,400	76,200	78,400	81,500	349,000	351,000
	Load	238.0	49.4	148.0	52.7	148.0	57.2	177.1	184.0
	Change		- 79%		- 64%		- 61%		+ 4%
	**		- 82%		- 63%		- 63%		+ 3%
Qu'Appelle below Craven Dam	Discharge	205,000	208,000	77,900	34,000	77,900	56,400	414,000	226,000
	Load	136.0	104.0	49.0	16.8	49.0	17.4	164.8	65.4
					(6.3)*		(12.6)*	(148.6)*	
	Change		- 24%		- 87%*		- 74%		- 56%
	**		- 25%		- 71%		- 64%		- 26%
Qu'Appelle above Pasqua Lake	Discharge	204,000	204,000	75,500	35,500	75,500	65,100	443,000	203,000
	Load	88.5	46.9	21.2	24.0	21.8	27.4	204.4	68.8
					(7.4)*		(14.6)*		
	Change		- 47%		- 65%		- 33%		- 66%
	**				- 26%		- 22%		- 27%

* Load adjusted to reflect similar time period due to missing data in 1971, 1973 or 1982
** Percent change in load between years after the loads are adjusted to reflect equal discharge

after tertiary treatment. The reduction was greatest in Wascana Creek, with reductions ranging from 60 to 91 percent and decreases with distance from the Regina tertiary treatment plant discharge. At the site above Pasqua Lake the reduction ranged from 22 to 47 percent. A number of factors probably contribute to this lower reduction downstream including: the sparse data base; instream processes resulting in the reduction of total phosphorus load with increasing distance from the source; manipulation of the river flow by diversion into Last Mountain Lake and irrigation practices; and the increased significance of non-point sources as distance from point sources increases.

The phosphorus loads based on the historical data can only be described as approximations. This can be more fully appreciated when trying to balance the annual phosphorus loads of Wascana Creek and the Qu'Appelle River below Moose Jaw River with the annual loads of the Qu'Appelle River at Lumsden (Table 5). The computation shows that summing the upstream phosphorus inputs can account for 41 to 153 percent of the phosphorus load at Lumsden. The cumulative annual upstream stream flows, which are based on a much more accurate data base, represent between 92 and 106 percent of the discharge at Lumsden. Comparison of the phosphorus load above Pasqua Lake based on the historical monthly sampling and the intensive sampling reported by Munro (1986) also show disparity (Table 2). The annual phosphorus loads based on the monthly samples were 105, 85, 115, and 156 percent of the load based on intensive sampling for the years 1980 through 1983. The variation between monthly load calculations were even greater, ranging from 40 to 248 percent of the monthly load calculated from the results of the intensive sampling. Based on these comparisons, one must agree with statements made by Cross (1978) and Tones (1981) that the historical water quality data are insufficient for detailed load determinations and loading models. These limitations not withstanding, comparison of the load calculations for similar flow-years suggests that the initiation of phosphorus removal by the City of Regina has substantially reduced the overall phosphorus load to the Qu'Appelle River.

Despite the 85 percent reduction in phosphorus concentration by the tertiary treatment of City of Regina sewage, it is still apparent that the treated effluent is a major contributor of phosphorus to the system, contributing approximately 24 tonnes of phosphorus annually to Wascana Creek (Table 6). This equates to 80 percent of the Wascana Creek loading, 1977 to 1983, and 26 percent of the total phosphorus load in the Qu'Appelle River at Lumsden. It should also be noted that the annual phosphorus load from the City of Regina has increased annually since tertiary

Table 5 Comparison of the Cumulative Upstream Phosphorus Load and Flow with Those at the Lumsden Location.

Year	Total phosphorus and flow in Wascana Creek above the Qu'Appelle River as a percent of that in the Qu'Appelle River at Lumsden		Total phosphorus and flow in the Qu'Appelle River Below Moose Jaw River a percent of that in the Qu'Appelle River at Lumsden		Cumulative Effect	
	Total Phosphorus	Flow	Total Phosphorus	Flow	Total Phosphorus	Flow
1971	22% (6 mos.)	58%	52% (6 mos.)	43%	74% (6 mos.)	101%
1972	18%	63%	75%	34% (10 mos.)	93%	97%
1973	14%	76%	104%	32%	118%	106%
1974	31%	65%	62%	27%	93%	92%
1975	52%	53%	101%	43%	153%	96%
1976	53%	61%	56%	36%	109%	97%
1977	42%	58%	42%	36%	84%	94%
1978	74%	52%	56%	50%	130%	102%
1979	85%	66%	41%	33%	126%	99%
1980	38%	56%	32%	41%	70%	97%
1981	70%	79%	24%	20%	149%	99%
1982	19%	58%	22%	36%	41%	94%

treatment began. This increase reflects the increasing volume of sewage from 1977 to 1983.

Table 6. Annual Phosphorus Loading From the Regina Sewage Treatment Plant After Tertiary Treatment.

Year	Discharge (dam^3)	Phosphorus Load (Tonnes)
1977	19,000	21
1978	21,000	17
1979	22,000	21
1980	20,000	20
1981	24,000	29
1982	26,000	27
1983(6 mos.)	13,000	17

Based on City of Regina Data.

There is reason to believe that under certain conditions in small fluvial systems such as the Qu'Appelle River, phosphorus uptake by macrophytes and other stream organisms coupled with sedimentary processes could result in removing phosphorus from the water. Therefore, one cannot simply impose the known city effluent loading upon the Qu'Appelle River loading and compute that portion of the instream load attributed to the effluent without considerable error. The phosphorus load data for Wascana Creek (Table 2) and the City of Regina effluent (Table 6) show that in 1980 and 1981 a portion of the phosphorus discharged in the sewage effluent was lost in Wascana Creek as the load in Wascana Creek above the Qu'Appelle River was less than the load discharged in the Regina sewage effluent. Similarly, there was a substantial loss of phosphorus between Lumsden and below Craven Dam. Both these years had low flow and phosphorus loss in Wascana Creek may have been only temporary. In a subsequent high flow year, it maybe remobilized and eventually reach the Qu'Appelle River. Between Lumsden and Craven Dam the loss of phosphorus was largely due to the diversion of water into Last Mountain Lake and irrigation of market gardens in the Lumsden to Craven area. The flow data (Table 3) shows that a 30 and 67 percent reduction in the flow occurred between Lumsden and Craven Dam in 1980 and 1981, respectively.

By computing moving four-year loads, it is possible to minimize the effect of anomalous years and also reduce the effect of ignoring travel time between sites. Moving four-year loads (Table 7) show that the diversion of Qu'Appelle River water and irrigation had least impact on the phosphorus loading during the very high flow period, 1974 to 1977. During these years the total discharge in the Qu'Appelle River at Lumsden was comparable to that entering the Fishing Lakes and the phosphorus loading into the Fishing Lakes was comparable to the load at Lumsden. Although there may be phosphorus loss in the river channel during the summer periods, this would appear to be minimal with respect to the amount of phosphorus transported over the four year time period. On the other hand, during the lower flow years since 1976 there was a 42 percent loss of phosphorus between Lumsden and Craven Dam. This loss can be attributed for the most part to the diversion of water into Last Mountain Lake and irrigation of farm land. Based on the limited data, this phosphorus loss appears to be relatively permanent, as the four year phosphorus load at the site below Craven Dam never exceeded the load at the Lumsden site. On the other hand, phosphorus loss due to instream processes appears to be only temporarily removed. This is evident in the four phosphorus loads for Wascana Creek which were always greater than the phosphorus load from the Regina sewage effluent, thus not reflecting the losses seen in the comparison of the annual phosphorus loads from these locations.

Table 7. Moving Four-Year Phosphorus Load in the Qu'Appelle River and Wascana Creek (Tonnes).

Time Period	Qu'Appelle Below Moose Jaw River	Wascana Creek above Qu'Appelle	Qu'Appelle at Lumsden	Qu'Appelle below Craven Dam	Qu'Appelle above Pasqua Lake
1974-77	261.2	403.4	570.3	514.7	569.5
1975-78	254.1	339.6	473.5	325.8	424.2
1976-79	266.3	210.4	419.7	264.9	295.4
1977-80	184.8	118.6	281.1	162.9	176.6
1978-81	194.8	108.9	278.9	165.0	147.8
1979-82	191.2	119.5	410.2	213.0	196.6

The phosphorus load from the City of Regina Tertiary treatment plant from 1977 through 1982 has been about 135

tonnes. If we assume the worst case, that all the phosphorus discharged from the sewage treatment plant reached the Qu'Appelle River, this would represent 26 percent of the phosphorus load in the Qu'Appelle River at Lumsden. This is a substantial reduction from 1970 when the phosphorus load from sewage effluent represented 57 percent of the phosphorus in the Qu'Appelle River (Qu'Appelle Basin Study Broad, 1972). Nevertheless, it still represents a major source of phosphorus for the system. Previously, it was stated that from 1978 to 1983, 42 percent of the phosphorus load at Lumsden was lost from the Qu'Appelle River between Lumsden and Craven Dam through irrigation, diversion to Last Mountain Lake, and/or instream processes. Therefore, in the worst case situation, if this loss is applied to the load from the Regina sewage effluent, approximately 78 of the 266 tonnes (29 percent) of the phosphorus entering the Fishing Lakes via the Qu'Appelle River from 1977 to 1982 originated from the Regina sewage effluent. It must also be pointed out that a significant portion of the 57 tonnes of phosphorus discharged from the Regina Tertiary treatment plant which did not reach the Fishing Lakes entered Last Mountain Lake and no doubt nurtured algal growth there.

4.2 Moose Jaw Sewage Effluent

In 1972, the Qu'Appelle Study Board estimated that the City of Moose Jaw sewage effluent contributed 12 percent of the phosphorus load in the Qu'Appelle system or approximately 40 tonnes of phosphorus annually. In 1978, Underwood McLellan Ltd. estimated the total annual phosphorus load from the Moose Jaw sewage discharge at approximately 32 tonnes. Thus, once tertiary treatment of Regina sewage began, the Moose Jaw sewage effluent became the largest single point contributor of phosphorus to the Qu'Appelle River. In June, 1982, the City of Moose Jaw began spray irrigating approximately 500 hectares with it sewage effluent. It was expected that this spray irrigation would reduce the phosphorus load to the Qu'Appelle River by about 50 percent. Work is continuing which will allow storage of sewage effluent from the non-irrigation season and to obtain more land for irrigation. Once completed and in operation this will further reduce the input of sewage to the Qu'Appelle River system from the City of Moose Jaw.

Assessment of the effectiveness of the spray irrigation on the phosphorus load in the Qu'Appelle River is not possible at the present time due to the sparse nature of the available data and the short period of time that the spray irrigation has been used. Time and continued monitoring

will be required if the effects on nutrient loads in the Qu'Appelle River of spray irrigation of Moose Jaw sewage are to be assessed.

5.0 INFORMATION GAPS

A number of information gaps have been identified through the assessment of the historical data. If a better understanding of nutrient loading in the Qu'Appelle River above the Fishing Lakes is required, these information gaps will need to be addressed. These gaps include: a lack of understanding of the instream processes as they affect the storage and release of nutrients; the significance of non-point sources of nutrients relative to the total nutrient load; and the effect of nutrient load into and out of Last Mountain Lake through the Qu'Appelle River diversion, both in terms of the impact on the quality of Last Mountain Lake and the effect on nutrient loads in the Qu'Appelle River.

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